KOPI til orientering

27 APR. 2000 PCT

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PCT/NO 00/00137
International Application No.

27 APR. 2000 (27.04.2000)
International Filing Date

PATENTSTYRET
Styret for det industrielle rettsvern
PCT International application
Name of receiving Office and "PCT International Application"

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

Applicant's or agent's file reference
(if desired) (12 characters maximum) Opti43PCT

Box No. I TITLE OF INVENTION
An apparatus comprising electronic and/or optoelectronic circuitry and method for realizing said circuitry

Box No. II APPLICANT

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

THIN FILM ELECTRONICS ASA
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Norway

☐ This person is also inventor.

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Facsimile No.
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Teleprinter No.

State *(that is, country)* of nationality: NO

State *(that is, country)* of residence: NO

This person is applicant for the purposes of: ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

EBBESEN, Thomas
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U.S.A.

This person is:
☐ applicant only
☒ applicant and inventor
☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: NO

State *(that is, country)* of residence: US

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☒ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☐ agent ☒ common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

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☐ **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Continuation of Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

If none of the following sub-boxes is used, this sheet should not be included in the request.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

NORDAL, Per-Erik
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Norway

This person is:

- [ ] applicant only
- [x] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: NO

State *(that is, country)* of residence: NO

This person is applicant for the purposes of:
- [ ] all designated States
- [ ] all designated States except the United States of America
- [x] the United States of America only
- [ ] the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:

- [ ] applicant only
- [ ] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of:
- [ ] all designated States
- [ ] all designated States except the United States of America
- [ ] the United States of America only
- [ ] the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:

- [ ] applicant only
- [ ] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of:
- [ ] all designated States
- [ ] all designated States except the United States of America
- [ ] the United States of America only
- [ ] the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:

- [ ] applicant only
- [ ] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of:
- [ ] all designated States
- [ ] all designated States except the United States of America
- [ ] the United States of America only
- [ ] the States indicated in the Supplemental Box

- [ ] Further applicants and/or (further) inventors are indicated on another continuation sheet.

Sheet No. . . . .

Box No.V DESIGNATION OF STATES

The following designations are hereby made under Rule 4.9(a) *(mark the applicable check-boxes: at least one must be marked)*:

Regional Patent

☒ AP **ARIPO Patent:** GH Ghana, GM Gambia, KE Kenya, LS Lesotho, MW Malawi, SD Sudan, SL Sierra Leone, SZ Swaziland, TZ United Republic of Tanzania, UG Uganda, ZW Zimbabwe, and any other State which is a Contracting State of the Harare Protocol and of the PCT

☒ EA **Eurasian Patent:** AM Armenia, AZ Azerbaijan, BY Belarus, KG Kyrgyzstan, KZ Kazakhstan, MD Republic of Moldova, RU Russian Federation, TJ Tajikistan, TM Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT

☒ EP **European Patent:** AT Austria, BE Belgium, CH and LI Switzerland and Liechtenstein, CY Cyprus, DE Germany, DK Denmark, ES Spain, FI Finland, FR France, GB United Kingdom, GR Greece, IE Ireland, IT Italy, LU Luxembourg, MC Monaco, NL Netherlands, PT Portugal, SE Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT

☒ OA **OAPI Patent:** BF Burkina Faso, BJ Benin, CF Central African Republic, CG Congo, CI Côte d'Ivoire, CM Cameroon, GA Gabon, GN Guinea, GW Guinea-Bissau, ML Mali, MR Mauritania, NE Niger, SN Senegal, TD Chad, TG Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT *(if other kind of protection or treatment desired, specify on dotted line)* . . . .

National Patent *(if other kind of protection or treatment desired, specify on dotted line)*:

☒ AE United Arab Emirates
☒ AL Albania . . . .
☒ AM Armenia . . . .
☒ AT Austria . . . .
☒ AU Australia . . . .
☒ AZ Azerbaijan
☒ BA Bosnia and Herzegovina . . . .
☒ BB Barbados
☒ BG Bulgaria . . . .
☒ BR Brazil . . . .
☒ BY Belarus . . . .
☒ CA Canada
☒ CH and LI Switzerland and Liechtenstein
☒ CN China . . . .
☒ CR Costa Rica . . . .
☒ CU Cuba . . . .
☒ CZ Czech Republic . . . .
☒ DE Germany . . . .
☒ DK Denmark . . . .
☒ DM Dominica
☒ EE Estonia . . . .
☒ ES Spain . . . .
☒ FI Finland . . . .
☒ GB United Kingdom
☒ GD Grenada
☒ GE Georgia . . . .
☒ GH Ghana . . . .
☒ GM Gambia
☒ HR Croatia . . . .
☒ HU Hungary . . . .
☒ ID Indonesia
☒ IL Israel . . . .
☒ IN India . . . .
☒ IS Iceland
☒ JP Japan . . . .
☒ KE Kenya . . . .
☒ KG Kyrgyzstan . . . .
☒ KP Democratic People's Republic of Korea . . . .
☒ KR Republic of Korea . . . .
☒ KZ Kazakhstan . . . .
☒ LC Saint Lucia
☒ LK Sri Lanka
☒ LR Liberia
☒ LS Lesotho . . . .
☒ LT Lithuania
☒ LU Luxembourg
☒ LV Latvia
☒ MA Morocco . . . .
☒ MD Republic of Moldova . . . .
☒ MG Madagascar . . . .
☒ MK The former Yugoslav Republic of Macedonia . . . .
☒ MN Mongolia
☒ MW Malawi . . . .
☒ MX Mexico . . . .
☒ NO Norway
☒ NZ New Zealand . . . .
☒ PL Poland . . . .
☒ PT Portugal . . . .
☒ RO Romania
☒ RU Russian Federation . . . .
☒ SD Sudan
☒ SE Sweden
☒ SG Singapore
☒ SI Slovenia . . . .
☒ SK Slovakia . . . .
☒ SL Sierra Leone . . . .
☒ TJ Tajikistan . . . .
☒ TM Turkmenistan . . . .
☒ TR Turkey . . . .
☒ TT Trinidad and Tobago . . . .
☒ TZ United Republic of Tanzania
☒ UA Ukraine . . . .
☒ UG Uganda . . . .
☒ US United States of America . . . .
☒ UZ Uzbekistan . . . .
☒ VN Viet Nam . . . .
☒ YU Yugoslavia . . . .
☒ ZA South Africa . . . .
☒ ZW Zimbabwe . . . .

Check-boxes reserved for designating States which have become party to the PCT after issuance of this sheet:

☒ DZ . . Algeria . . . .
☐ . . . .

Precautionary Designation Statement: In addition to the designations made above, the applicant also makes under Rule 4.9(b) all other designations which would be permitted under the PCT except any designation(s) indicated in the Supplemental Box as being excluded from the scope of this statement. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. *(Confirmation (including fees) must reach the receiving Office within the 15-month time limit.)*

Box No. VI PRIORITY CLAIM ☐ Further priority claims are indicated in the Supplemental Box.

Filing date of earlier application (day/month/year)	Number of earlier application	Where earlier application is: national application: country	regional application:* regional Office	international application: receiving Office
item (1) 30 April 1999 (30.04.99)	19992124	NO		
item (2)				
item (3)				

☒ The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) *(only if the earlier application was filed with the Office which for the purposes of the present international application is the receiving Office)* identified above as item(s): (1)

* *Where the earlier application is an ARIPO application, it is mandatory to indicate in the Supplemental Box at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed (Rule 4.10(b)(ii)). See Supplemental Box.*

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) *(if two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used):*

ISA / SE

Request to use results of earlier search; reference to that search *(if an earlier search has been carried out by or requested from the International Searching Authority):*

Date *(day/month/year)*	Number	Country *(or regional Office)*

Box No. VIII CHECK LIST; LANGUAGE OF FILING

This international application contains the following **number of sheets**:

request	:	4
description (excluding sequence listing part)	:	21
claims	:	5
abstract	:	1
drawings	:	11
sequence listing part of description	:	
Total number of sheets	:	42

This international application is **accompanied** by the item(s) marked below:

1. ☒ fee calculation sheet
2. ☒ separate signed power of attorney (2)
3. ☐ copy of general power of attorney; reference number, if any:
4. ☐ statement explaining lack of signature
5. ☐ priority document(s) identified in Box No. VI as item(s):
6. ☐ translation of international application into (language):
7. ☐ separate indications concerning deposited microorganism or other biological material
8. ☐ nucleotide and/or amino acid sequence listing in computer readable form
9. ☐ other *(specify)*:

Figure of the drawings which should accompany the abstract: 1a, 1b, 11

Language of filing of the international application: ~~Norwegian~~ ENGLISH

RO/NO

Box No. IX SIGNATURE OF APPLICANT OR AGENT

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).

THIN FILM ELECTRONICS ASA

Geirr I. Leistad
IPR & Legal Department Manager

For receiving Office use only

1. Date of actual receipt of the purported international application: 27 APR. 2000 (27-04-2000)
2. Drawings: ☒ received: ☐ not received:
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:
4. Date of timely receipt of the required corrections under PCT Article 11(2):
5. International Searching Authority (if two or more are competent): ISA / SE
6. ☐ Transmittal of search copy delayed until search fee is paid.

For International Bureau use only

Date of receipt of the record copy by the International Bureau:

v71 100...

PATENT COOPERATION TREATY

RECD 03 AUG 2001
WIPO PCT

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70) 14

Applicant's or agent's file reference Opti43PCT	**FOR FURTHER ACTION** See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/NO00/00137	International filing date *(day/month/year)* 27/04/2000	Priority date *(day/month/year)* 30/04/1999
International Patent Classification (IPC) or national classification and IPC H05K3/10		
Applicant THIN FILM ELECTRONICS ASA ET AL.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 7 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 30 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand 29/11/2000	Date of completion of this report 31.07.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Batev, P Telephone No. +49 89 2399 7970

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/NO00/00137

I. Basis f the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

Description, pages:

1-23	as received on	30/05/2001	with letter of	25/05/2001

Claims, No.:

1-34	as received on	30/05/2001	with letter of	25/05/2001

Drawings, sheets:

1/13,3/13-6/13, 8/13-13/13	as originally filed			
2/13,7/13	as received on	30/05/2001	with letter of	25/05/2001

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	2-32, 34
	No:	Claims	1, 33
Inventive step (IS)	Yes:	Claims	none
	No:	Claims	1 - 34
Industrial applicability (IA)	Yes:	Claims	1 - 34
	No:	Claims	none

2. Citations and explanations
   see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

Re Item VIII

Certain observations on the international application

1. Claim 1 contains a multitude of expressions such as "and/or" which introduce a large number of different possibilities to interpret the claim.

Thus, for example, claim 1 can relate to "an apparatus comprising electronic circuitry" or to "an apparatus comprising optoelectronic circuitry" or to "an apparatus comprising electronic and optoelectronic circuitry".

All the possible alternatives covered by the wording of claim 1 lead to a claim whose scope is so unclear that a full examination is not possible.

2. The terms "active regions" and "active areas" are too general and render the definition of the scope for which protection is sought unclear. For the purpose of examining the claims the term "active regions" is, therefore, interpreted as defined in the description (see p. 7, l. 5-12), i.e. "the active regions in an element are defined by exposing portions of the said element to the exterior surroundings" or "an active region of an element corresponds to an end point". The term "active areas" is considered to have identical meaning. The Applicant is once again advised to introduce reference signs in order to facilitate the understanding of the claims.

3. The expression "specific functions or combinations thereof which implement, but are not limited to" has no limiting effect on the scope of claim 1; that is to say, the features following this expression are to be regarded as entirely optional (Guidelines Chapter III-4.6).

4. The expression "specific physical or chemical influences" has no well-recognised meaning and renders the definition of the subject-matter unclear. It should be replaced by a more precise wording (Guidelines, Chapter III-4.5).

5. The expression "said structures realizing all the above-mentioned mechanisms being integrated in the elements of the apparatus and forming a part thereof" used in the last two lines of claim 1 implies that all different structures defined in said claim should be present in the claimed apparatus. This seems to be in contradiction with the remaining part of the claim which specifies different structures integrated in the apparatus as alternatives (see claim 1, lines 21-23 and 35-36).

6. The embodiment of the invention, a memory device, described on pages 14 and 15, and shown in figure 9d does not fall within the scope of the device claims 1 - 32 which define an apparatus comprising display structures and/or sensor structures. This inconsistency between the claims and the description leads to doubt concerning the matter for which protection is sought, thereby rendering the claims 1 - 32 unclear (Article 6 PCT; see also Guidelines, Chapter III-4.3).

Re Item V

Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following documents:

D1: EP-A2-0506298, 30 September 1992
D2: CH-A5-682964, 15 December 1993
D3: US-A-3277347, 4 October 1966
D4: US-A-3130257, 21 April 1964

A copy of document D3, which is cited for the first time, is annexed.

1. Insofar as the examiner can understand the subject matter (see Re Item VIII), the following is prima facie pointed out:

Document D1 discloses an apparatus
comprising optoelectronic circuitry for implementing optical functions (abstract; col. 7, l. 35-46),
wherein the circuitry is integrated in two dimensions (col. 6, l. 37-49),
wherein the circuitry comprises elements in the form of fibres (col. 6, l. 16-29),
said elements interfacing in a predetermined pattern such that said circuitry are realized with intersections in physical contact between the elements thereof (col. 7, l. 35-37),
wherein said predetermined pattern is generated by integrating physically two or more of said elements in a fabric-like structure by weaving (col. 1, l. 3-6),
wherein said elements include transparent, non-transparent, conducting, or insulating materials (col. 4, l. 1-5),
wherein at least some of said elements according to their material properties form optical transmission lines in said circuitry (col. 6, l.39-40),

said optical transmission lines conveying optical energy between points in said fabric-like structure (col. 7, l. 43-53),

wherein at least some of said elements comprise spatially defined extended active regions (col. 7, l. 35-37),

wherein at least some of said elements in portions of said fabric-like structure are adapted for emitting optical energy (col. 3, l. 2-6; col. 7, l.31-33 and 43-45),

wherein coupling, emitting and absorbing mechanism are realized by two active regions in respectively one or more elements and which are in mutual physical contact (col. 7, l. 29-33),

whereby active areas form display structures for displaying visual information and images or sensor structures for sensing and detecting physical influences which are conveyed by means of the elements of the apparatus or from sources exterior to the apparatus (col. 3, l. 2-6; col. 5, l. 43-46; col. 7, l.29-33).

The subject matter of claim 1 lacks, therefore, novelty (Article 33(2) PCT, see also Guidelines Chapter IV-7.1).

2. For the sake of completeness, the attention of the applicant is drawn to documents D2 - D4, which are considered to be particularly relevant.

Document D2 discloses an apparatus

comprising electronic circuitry for implementing electronic functions (title),

wherein the circuitry is integrated in two dimensions (col. 1, l.31-36),

wherein the circuitry comprises elements in the form of wires (abstract),

said elements interfacing in a predetermined pattern such that said circuitry are realized with intersections in physical contact between the elements thereof (col. 2, l. 33-40),

wherein said predetermined pattern is generated by integrating physically two of said elements in a fabric-like structure by weaving (abstract),

wherein said elements include conducting materials (abstract),

wherein at least some of said elements according to their material properties form electrical transmission lines in said circuitry (abstract),

said electrical transmission lines conveying electrical energy between points in said structure (abstract),

wherein at least some of said elements comprise spatially defined extended active regions (col. 3, l. 1-4),

wherein at least some of said elements in portions of said structure are adapted

for interacting with each other by an exchange of electrical energy (col. 2, l.41-45),

wherein coupling mechanism is realized by two active regions in respectively one or more elements and which are in mutual physical contact (col. 2, l.38-45),

whereby active areas form sensor structures for sensing and detecting physical influences which are conveyed by means of the elements of the apparatus (col. 2, l. 38-45).

Consequently, the technical features of claim 1 are known in combination from D2 as well.

3. Document D1 discloses a method for integrating circuitry in two dimensions (col. 6, l. 37-49),

wherein the circuitry comprises elements in the form of fibres (col. 6, l. 16-29),

wherein said circuitry is optoelectronic circuitry for implementing optical functions (abstract; col. 7, l. 35-46),

the method comprising joining two elements into a fabric-like structure by weaving (col. 1, l. 3-6),

such that the elements interface in a predetermined pattern, realizing the circuitry with the elements intersecting in physical contact in the fabric-like structure (col. 7, l. 35-37),

and by providing spatially defined extended active regions in the elements at the intersections thereof (col. 7, l. 35-37),

such that two active regions thus contacting each other in each case are realized with coupling mechanisms dependent on the material properties of the active regions in question (col. 7, l. 29-33),

said elements being made of transparent, non-transparent, conducting or isolating materials (col. 4, l. 1-5).

The subject matter of independent claim 33 is, therefore, not new (Article 33(2) PCT).

4. Dependent claims 2 - 32 and 34 do not seem to contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of inventive step (Article 33(3) PCT).

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An apparatus comprising electronic and/or optoelectronic circuitry and method for realizing said circuitry

The present invention concerns an apparatus comprising electronic and/or optoelectronic circuitry for implementing electronic and/or optical functions, wherein the circuitry is realized and/or integrated in two or more dimensions. The invention also concerns a method for realizing and/or integrating circuitry in two- or more dimensions in an apparatus of this kind comprising electronic and/or optoelectronic circuitry for implementing electronic and/or optical functions in the apparatus, wherein the circuitry comprises elements in the form of wires, fibres, ribbons, strips or multicomponent filaments and/or combinations thereof.

In particular, the present invention concerns integrating filament-like electrical and/or optical conduits into two- and three-dimensional physical structures for creating electronic or optoelectronic circuitry, sensors and/or emitters. The spatial extent or region of influence of such circuitry, sensors and/or emitters is controlled by specific definition of the electrical and/or optical properties of the individual filaments and how they are incorporated into the structures.

The development of integrated circuits on silicon and semiconductor compound materials has revolutionized the electronic industry. However, the ever-increasing complexity and costs of higher integration technology has generated interest in novel materials and methods.

For instance, progress in conductive polymers and organic materials has led to novel displays, diodes and field-effect transistors using these materials. See G. Horowitz "Organic field effect transistors" Adv. Mat. Vol. 10, pp. 365-377 (1998); D. Pede & al. "A general-purpose conjugated-polymer device array for imaging" Adv. Mat. Vol 10, pp. 233-237 (1998); R.H.Friend et al. "Electroluminescence in Conjugated 'Polymers", Nature 397, pp.121-128 (1999).

Thin-film-based inorganic semiconductor technologies compatible with low temperature-resistant packaging and substrate materials are under rapid development, and include amorphous silicon as well as polysilicon and microcrystalline silicon. In this connection, see, e.g. J.G. Blake & al.,

"Low-temperature polysilicon reshapes FPD production", Solid State Technology, pp.151-161 (May 1997).

Defect tolerant architectures have been proposed to circumvent the problems of trying to produce defect free chips, for instance by J.R. Heath & al., "A defect-tolerant computer architecture: opportunities for nanotechnology", Science, Vol. 280, pp. 1716-1721 (June 12, 1998).

Such novel materials and methods open up entirely new opportunities in electronics and optoelectronics that extend much beyond providing an evolutionary route to alleviating problems and limitations adhering to the present state of the art. Unfortunately, present-day semiconductor-oriented technologies are totally inadequate for exploiting the true potential of these novel materials and methods, and there exist pressing needs for complementing technologies. One area of particular importance is that of gaining freedom from the dominating role of the substrate.

In traditional silicon-based technologies, the electronic functionality is derived from the semiconducting silicon substrate, which severely restricts opportunities for extensions into the third dimension. Furthermore, physical dimensions are restricted, and the traditional lithographic processes provide only limited flexibility with respect to intra-device connectivity. This includes both the physical characteristics of the connecting lines themselves and how they can be positioned throughout the device structures in question. Typically, the substrate and its layered superstructures contain electrical interconnects where electric currents flow in patterned strip- or ribbon-like conducting paths that have been created by subtractive or additive processes.

Subtractive processes are well-known and much used in the semiconductor industry, and involve wet or dry etching whereby conducting material is removed from portions of the substrate. Conducting material is retained in regions where a protective layer has been applied in the patterns desired, e.g. by optical lithography. Typically, all modern microelectronic circuits involve multiple step lithography processes where image(s) of parts or all of the circuitry, mostly wires, and devices are transferred to the substrate. This requires careful register between each step, the more so as the features become smaller and smaller. The substrate must be extremely flat and rigid. Furthermore, the circuitry cannot be continuous through this approach. Several chips have to be made individually on one wafer at the time.

Furthermore, the integration of electronic and optoelectronic circuits is extremely difficult by such methods. It would therefore be highly advantageous to find microcircuit fabrication methods which eliminate lithographic processes altogether and allow for flexible continuous fabrication of electronic and optoelectronic circuits.

Additive processes have hitherto been less used in electronic circuits, but may become important in the future. They include microprinting and micromolding of conducting inks or solid state conductors, screen printing and more exotic means such as laser mediated deposition (see, e.g.. H. Yabe & al., "Direct writing of conductive aluminum line on aluminum nitride ceramics by transversely excited atmospheric CO2 laser", APL 71 2758 (1997)).

The present invention introduces the concept of woven electronics as a new generic approach to making and assembling electronic and optoelectronic devices and apparatus, in particular by exploiting opportunities that arise with the advent of novel electronic materials. This implies a radical departure from present state of the art.

This is substantiated by searches performed in the literature have to a small extent been able to identify any relevant prior art. Yet there is for the sake of completeness in order to briefly discuss patent documents which touch upon circumstances of general relevance for the present invention.

Thus there is from DE 31 16 348 A1, "Elektrische Verbindungseinrichtung" (Oscar Alonso, USA), and WO96/38025 A1, "Composite materials" (Geroge William Morris, Great Britain) known substrates which incorporate woven layers with electrical conduits. The latter are, however, applied after the weaving process has been finished, by methods such as etching, printing or electron sputtering.

JP-05299533, "Electronic part mounting board and electronic part device using the same" (Ohigata Naoharu, Japan) discloses a woven structure incorporating conducting wires interspersed with electrically insulating filaments. However, the focus is here substantially on providing alternative substrates to replace circuit mounting boards subjected to thermal and mechanical stress and the publication discloses in principle neither a new

kind of functionality nor novel apparatuses which can be seen to be of relevance for the present invention.

Further can be mentioned US patents Nos. 4 913 744 and 5 902 416 (both H. Hoegel & al.) which concern wire-like, band-like and rod-like solar cells which in at least one embodiment are provided in a woven structure. It is stated that the separate solar cells in the woven structure can be electrically connected at the underside of the crossing in the web with a counter-electrode in order to realize charge transfer between centre electrodes of the solar cells. It is also stated that the contact effect can be improved by a compression of solar cells in the form of wires or the crossing points either by thermal treatment or by use of electrically conducting adhesive. The object in this case is to achieve an improved arrangement of the solar cells, including among other by allowing the realization of tandem cells.

Generally there is both from the patent literature and other literature known to include conducting metal wires by weaving into a large number of objects. This includes meshes, which e.g. act as electrical shielding in housings, and electrodes and filters in material science. Metallic fabrics and metallic embroidery are used to make decorative and protective clothes. Conducting wires are integrated in fabrics to provide clothing and furniture, which prevent the formation of electrostatic charge or alternatively used for providing electrical heating. In so-called "smart clothes" such woven structures may for instance be used for connecting or providing the clothes and apparels with electronic devices and sensors. For instance can in this connection be mentioned US patent No. 5 906 004 (Lebby & al.) (assigned to Motorola Inc.) which discloses a textile fabric with a number of electrically conducting fibres, which are able to provide either a wire-based or wireless connection between the textile fabric and a portable electronic device. The intention is that the textile fabric may be used for manufacturing functional clothes and other objects of woven textile fabric with the intention of increasing the functionality of the clothing or the functionality of the object. Typically are electrically conducting fibres disclosed in the capacity of providing an interconnection to a portable electronic device of some kind or other. Concerning the development in this area it can also generally be referred to S.E. Braddock and M. O'Mahony, "Techno Textiles – Revolutionary Fabrics for Fashion and Design", ch. 2, Thames and Hudson,

New York (1998). Summing up a survey of the prior art illuminated by the above-mentioned patent literature and other literature shows that the use of a woven structure which provides electrically conducting and electrically screening functions is per se well-known and the same is also the case for uses of such structures for providing electrical connections between discrete, separate or surface-mounted devices. Inherent features of such woven structures for providing a more comprehensive electronic or optoelectronic functionality is not touched upon at all.

To conclude, in order to realize the potential in a wide range of emerging electronic and optoelectronic materials and methods, there is a need for complementing technologies, which are not within the present-day state of the art. Prominent among such technologies are those that can provide electrical and optical interconnections in two and three dimensions, with high spatial density, high signal speed potential and small crosstalk. Also prominent are technologies and materials suitable as structural platforms for large area electronics and/or three dimensional device architectures.

A primary object of the present invention is to provide a lithography-free process to produce electronic and optoelectronic devices, apparatus and circuits in sheet-like or fabric form, or in three-dimensional structures.

It is a further object of this invention to provide for continuous circuits over large areas and in mechanically flexible final products, which can be shaped to a desired environment or form factor.

It is still a further object of the present invention to provide intra- and inter-device electrical and optical connections that can carry high-speed signals with very low crosstalk.

Another object of the invention is to provide methods to integrate electronic and optical circuits in a continuous matrix.

Yet another object of the invention is to create functional devices by weaving, knitting, crocheting, knotting, stitching and/or combinations thereof.

The above-mentioned objects and advantages are according to the invention realized with an apparatus wherein the circuitry comprises elements in the form of wires, fibres, ribbons, strips, or multicomponent filaments and/or

combinations thereof, said elements interfacing in a predetermined pattern such that said circuitry are realized with intersections in physical or near physical contact between the elements thereof, wherein said predetermined pattern is generated by integrating physically two or more of said elements in a fabric-like structure by any of the following processes, viz. weaving, knitting, crocheting, knotting, stitching and/or combinations thereof, wherein said elements include transparent, non-transparent, conducting, semiconducting or insulating materials and/or combinations thereof, wherein at least some of said elements according to their material properties form electrical or optical transmission lines or isolators in said circuitry, said electrical or optical transmission lines conveying respectively electrical or optical energy between points and/or areas in said fabric-like structure, and or between the apparatus and its surroundings, wherein at least some of said elements comprise spatially defined extended active regions, wherein at least some of said elements in portions of said fabric-like structure are adapted for emitting or absorbing electrical, chemical, mechanical or optical energy or for interacting with each other by an exchange of energy of the aforementioned kinds, wherein switching, coupling, emitting and absorbing mechanism in any case are realized by two or more active areas in respectively one or more elements and which are in mutual physical or near physical contact, whereby active areas in a contact of this kind realizes one or more specific functions or combinations thereof which implements, but are not limited to switching structures and/or diode structures with junctions specified by the materials in the contacting active regions, couplers for transmitting signals between the elements, memory structures for storing information and allowing addressing operations thereto to take place via further contacting, switching and/or coupling structures, and wherein further emitting and absorbing as well as detecting mechanisms are realized by active areas exposed to the exterior, whereby active areas of this kind respectively form display structures for displaying visual information and images and/or sensor structures for sensing and detecting specific physical or chemical influences which are conveyed by means of the elements of the apparatus or from sources exterior to the apparatus, said structures realizing all the above-mentioned mechanisms being integrated in the elements of the apparatus and forming a part thereof.

In an advantageous embodiment of the apparatus according to the invention, the elements are provided in the predetermined pattern forming a substantially two-dimensional fabric-like structure, while in another advantageous embodiment of the apparatus according to the invention the elements are provided in the predetermined pattern forming a substantially

three-dimensional fabric-like structure. In the latter embodiment the elements then preferably each has a length and is provided in a spatial distribution such that the positions of the end-points of the elements in the fabric-like structure defines a spatial pattern or grid.

In advantageous embodiments of the apparatus according to the invention it is preferred that some of the transmission lines respectively are twisted pairs, coaxial cables, strip lines or optical fibres.

In advantageous embodiments of the apparatus according to the invention the active regions in an element are defined by exposing portions of the said element to the exterior surroundings thereof. Preferably the active regions of an element are lengthwise extended therein, or an active region of an element corresponds to an end-point thereof.

In advantageous embodiments of the apparatus according to the invention some of the elements are provided with a protective shielding or cladding, the active regions in these elements being provided by removing the shielding or cladding at selected portions thereof, or the active regions of the elements being provided in selected portions of the elements and exposed in the surface of the fabric-like structure or protruding therefrom at selected locations thereof, or the active regions of the elements being defined by exposing portions thereof to spatially selective physical or chemical influences.

In an advantageous embodiment of the apparatus according to the invention some of the transmission lines are at least one conductor embedded in an exterior cladding comprising at least one organic semiconducting material, and active regions are defined therein by contacting said transmission lines with other transmission lines of the same kind or with other transmission lines in intersections which comprises at least one non-isolated or unclad conductor only, whereby semiconducting junctions are formed at the contact points of said intersections. In this case it is preferred that the semiconducting junctions are formed spontaneously upon contacting, or that preferably at least one of the semiconducting junctions is a diode junction, or that the organic semiconducting material preferably is a semiconducting conjugated or non-conjugated polymer.

In an advantageous embodiment of the apparatus according to the invention at least some of the elements over some of their length are shielded against any interactions in form of an exchange of energy between each other or to the exterior surroundings, whereas one or more unshielded portions thereof are adapted for interactions of this kind by being in physical or near-physical contact with corresponding portions in other elements, and it is then preferred that the unshielded portions of the elements are located at the intersections thereof.

In yet another advantageous embodiment of the apparatus according to the invention it is a two- or three-dimensional optoelectronic display and the elements are then preferably signal transmission lines. Wherein the display is a two-dimensional display the elements are then preferably provided in a two-dimensional array. In the latter case the elements intersect in a substantially regular pattern or grid, said elements at the intersections thereof being adapted for absorbing or emitting electrical or optical energy and at least a portion of at least one element in an intersection can then be a pixel of the display. Wherein the display is a three-dimensional display, the elements are preferably provided in a three-dimensional array, and they can then intersect in a spatially regular pattern or grid, said elements in the intersections thereof being adapted for emitting or absorbing electrical or optical energy. In this case a portion of at least one element in an intersection can preferably be a pixel of the display.

Wherein the active regions of the elements in the apparatus according to the invention are provided in selected portions of the elements and exposed in the surface of the fabric-like structure or protruding therefrom at selected locations thereof, it is advantageous that the active regions of this kind are pixels in the display, said active regions being either a loop-like portion of an element or an end-point thereof.

In an advantageous embodiment of the apparatus according to the invention it can comprise respectively one or more discrete electronic, optoelectronic or optical devices or combinations thereof, and one or more discrete devices can then preferably be physical or chemical sensors connected to at least one of the elements.

Finally in an advantageous embodiment of the apparatus according to the invention one or more of the elements can be a physical or chemical sensor.

The above-mentioned objects, advantages and features are according to the invention also achieved with a method which is characterized by joining two or more elements into a fabric-like structure by any of the following processes viz. weaving, knitting, crocheting, knotting, stitching and/or combinations thereof, such that the elements interface in a predetermined pattern, realizing the circuitry with the elements intersecting in physical or near-physical contact in the fabric-like structure, and by providing spatially defined extended active regions in the elements at the intersections thereof, such that two or more active regions thus contacting each other in each case are realized with switching, coupling, emitting or absorbing mechanisms dependent on the specific physical or material properties of the active regions in question, said elements being made of transparent, non-transparent conducting, semiconducting or insulating materials and/or combinations thereof.

In the method according to the invention a shielding or cladding material is preferably provided on a surface of the elements before joining into the fabric-like structure, said shielding or cladding material being removed from some elements or from selected portions thereof at selected locations in the fabric-like structure such that at least some of the selected portions form active regions with specific physical properties of material properties.

The invention shall now be described in more detail, with discussions of exemplary non-limiting embodiments showing various embodiments of the present invention and in conjunction with the appended drawings, wherein

figure 1 shows example of basic weaves such as the plain (a), the triaxial (b), the twill (c), the leno (d) and the satin (e) weaves,

figure 2 examples of knits such as the plain (a), the double (b), the warp (tricot) (c) knit and various weft knit stitches (d),

figure 3 examples of multicomponent fabrics such as the weft insertion warp knit fabric (a), pile (b) and carpet (c) fabrics,

figure 4a-e examples of possible shapes and compositions of the fibers, wires and ribbons composing the electronic or optoelectronic fabric,

figure 5 a simple loop detector woven into the fabric matrix,

figure 6 a detector using a pile of fibers as sensor,

figure 7 the integration of various functional units into the fabric matrix,

figure 8a-c a display panel or a two-dimensional photodetector,

figures 9a,b,c,d principles and embodiments of memory or switching arrays according to prior art and according to the present invention,

figures 10a, 10b and 10c dual-conductor structures of relevance as weaving filaments, and

fig. 11 an example of an apparatus realized as a flexible sheet-like structure.

After a discussion of general aspects of the invention, examples of embodiments shall be given. As already stated, the given objects of the invention are specifically realized by weaving, knitting, crocheting, knotting and/or stitching a combination of conducting, semiconducting, superconducting and/or insulating wires or fibers and/or optical fibers. These techniques, in the following also termed joining processes, provide a high degree of control and constructive flexibility in creating integrated physical structures with electrical and/or optical functionality in two and three dimensions.

Control is in part related to the use of strands in the weaving, knitting, crocheting, knotting and/or stitching processes that are pre-made under precisely controllable conditions before being incorporated into the final structure. Each strand can be made to include several different materials and sub-structures, e.g. in the form of electrical multiconductor cables, metallic filaments cladded with polymers that engender electronic functionality when brought into contact with other components in a woven structure, or optical fibers with cladding for protection or environmental sensing.

Control is also a consequence of the degree of topographic order in two and three dimensions that can be achieved by weaving, knitting, crocheting, knotting and/or stitching processes, where the identity and relative positions of the strands are strictly defined according to a predetermined protocol.

Flexibility in creating two- and three-dimensional physical structures and achieving associated electronic and/or optical functionality springs from the diversity and sophistication that can be achieved by weaving, knitting, crocheting, knotting and/or stitching processes, as demonstrated by the present state of the art within the textile industries. With the advent of woven

electronics, computer-aided design and manufacturing shall become important tools for creating new architectures and processes specifically targeting the needs and opportunities in that field.

Flexibility is also achieved by the absence of fundamental physical size limits: The strands in the weave may be as long as required for any given application and the ensuing circuit or apparatus may be scaled in size, in principle without limit. The form factor, i.e. size and shape of the woven apparatus may be chosen with few constraints. Examples of this include thin sheets as well as complex three-dimensional structures. Finally, circuits and apparatus according to the invention can be literally, physically flexible when made in a wide range of embodiments.

A major aspect of the present invention is that it provides opportunities for creating integrated circuits of a radically new type, where electronic and/or optical functionality is embedded throughout the woven, knitted, crocheted, knotted and/or stitched structures, with the strands in the structures acting as signal and power conduits and creating or promoting structural integrity. As shall be described in detailed examples below, the strands can provide many forms of functionality, either at points where different strands come into physical contact with each other and create junctions that exhibit e.g. luminescence, memory or switching behaviour, or in restricted regions where strands are exposed to external influences such as light, heat or chemical species, or distributed along portions of the length of individual strands, or at specific points where attachment has been made to discrete functional components.

Figures 1, 2 and 3 give examples of standard weaving and knitting patterns and combinations thereof which are applicable, bur not exclusively, to generate circuits and devices which then form an electronic or optoelectronic fabric as used in the apparatus according to the present invention.

Specifically fig. 1a shows plain weave, fig. 1b a triaxial weave which can be regarded as a variant of the plain weave, but with diagonal wefts, fig. 1c twill weave, fig. 1d leno weave wherein two weft yarns are twisted around each other, and fig. 1e satin weave. Similarly fig. 2a shows specifically plain knit, fig. 2b double knit, fig. 2c tricot knit and figs. $2d_1$-$2d_5$ examples of various weft knit stitches or meshes. Fig. 3a shows specifically an example of a warp knit fabric with inserted weft, fig. 3b a form of pile weaving wherein the

weft is forming piles, and figs. 3c and 3d respectively two different embodiments of carpet weaves.

The fibers, wires, ribbons composing the circuits can have cross sections that are round, oval, square, rectangular, polygonal or any other desired shape as shown in fig. 4a. They may be single-component or multicomponent as shown in fig. 4b-d. These will make up the basic elements of the textile or fabric forming the apparatus according to the invention, but shall in order to avoid misunderstandings be referred to as fibers in the following description. The components of multicomponent fibers can be arranged in different ways depending on the needs and applications. For instance a given fiber can be multicomponent in the cross section and/or along the axis of the fiber, causing it to exhibit spatially varying physical, chemical and/or electrical properties. The single-component fibers and different components in multicomponent fibers may be either electrically conductive, semiconducting, superconductive, insulating, optically conductive or any combination thereof, but are not limited to these. The components can be any sensor or detector material such as those activated by light, heat, chemicals, electric and magnetic fields. Individual fibers, single component or multicomponent ca be bundled or braided as shown in fig. 4e.

The electronic or optoelectronic fabric can be composed of single component or multicomponent fibers combined in various ways as exemplified by the patterns and weaves mentioned above in connection with figs. 1, 2 and 3. The fabric can also be assembled from bundles or braided fibers, or from more complex filament-like structures such as electrical cables with multiple conductors separated by a dielectric. Fibers of different types and different dimensions can be combined in the fabric. For example, alternating conducting and insulating fibers might be useful in some applications. The crossing of two or more fibers in the fabric are natural loci for device functionality such as memory, switches, sensors, etc. The crossing can be left as such or fused or bonded depending on the desired product.

There are no size limitations for these devices by the present invention. Individual devices can be created by weaving a given pattern at a chosen position in the fabric matrix as illustrated in figs. 5, 6 and 7. Fig. 5 shows a loop detector formed in the fabric matrix, while fig. 6 shows a pile sensor, i.e. the inclusion of piles of a number of small sensor fibers in the matrix,

which provides a detector with large surface area and consequently high sensitivity. Such devices can be woven, knitted or stitched into the fabric matrix. Functional units in the apparatus and other devices may further be combined by being woven, stitched or knitted into a larger fabric matrix as shown in fig. 7, which specifically shows respectively a memory device, a sensor device and a display inserted in the fabric matrix and connected to the outside thereof as shown in the figure. Multilayer knitting will also be possible in order to realize functional devices in the fabric matrix and the finished electronic fabric matrix which forms the apparatus can in a final production step be impregnated with some material or another in a suitable manner, e.g. with an insulator.

Functional components, circuits or optoelectronic devices in the apparatus according to the present invention may be addressed from the edges of the fabric or anywhere in the matrix by weaving, knitting or stitching in connecting wires.

Fig. 8a-c shows a display device or two-dimensional photodetector in matrix form as rendered in figs. 8a,c. It is assembled by weaving two types of fibers as shown in figs. 8a,b. One is a bi-component fiber with a core consisting of a conducting material M1 coated with an active material A which for this embodiment is either an electroluminescent material or a photoconductive material. The other fiber is a conductor M2. M1 and M2 will typically have different work functions. Each crossing then becomes a pixel of the two-dimensional array, as in fig. 8c. For a colour display panel, the electroluminescent material can be varied from one fiber to the next. For instance, three successive fibers will correspond to the three colours: red (R), green (G) and blue (B). Alternatively, different voltages can be used to generate different colors at each pixel. The pixel density achieved by the invention will be much higher than those of prior art. The high density of pixels in such a fabric is ideal for high definition applications.

Fig. 9a shows a memory or a switching array, where specific addresses in the array are located in a crosspoint matrix fashion, i.e. by selectively activating the row and column that cross at the point where the memory or switching cell is located. Variants of this basic scheme are employed extensively in the electronics industry, often with semiconductor components embedded within the matrix structure.

Typical embodiments of crosspoint matrices within the present state of the art are built on a silicon chip, where traditional lithographic silicon technologies are used to create the conducting matrix gridlines, etc. According to the present invention, however, the rows and columns in a matrix addressing system can be formed by wires crossing each other in a weave. An example is given below.

A class of memory devices that are of particular interest in conjunction with novel thin film and organic electronic materials employ passive matrices, i.e. matrices where the functional cell at each crossing point is very simple, without intra-cell transistor-based switching circuitry. One way of achieving addressability is to employ rectifying diodes to block parasitic current paths between the two wires that cross at the selected cell, such as shown in fig. 9b. Such "sneak currents" are a well-known problem in passively addressed matrices, as is the remedy of inserting diodes at the crossing points. Unfortunately, achieving this by traditional semiconductor techniques (lithography, etching, doping, plating...) is complicated and gives no competitive advantage over the alternatives, which are the well-known active-matrix based architectures used in ROMs, DRAMs, SRAMs, etc.

Recently, it has been shown, for instance in the International Patent Application PCT/NO98/00185 which has been assigned to the present applicant, that very compact and simple matrices with diode-connected crossing points can be made by using conjugated polymers that spontaneously create a diode junction when the polymer contacts a metal surface. This opens up opportunities for passive matrix memory devices where high-functionality organic and/or inorganic materials fill the volume between the crossing matrix electrodes, performing memory and addressability functions. A generic cell is shown in fig. 9c. Here, one of the electrodes is contacting a material which forms a rectifying junction at the electrode/material interface, while the rest of the cell volume is filled with a memory material which controls the electrical characteristics of the cell according to the logic state (e.g. storing a logic "0" or "1"). This memory material may simply be a masked insulator in the ROM case, or it may be a material which can be switched between a high and a low impedance state to form a WORM (Write Once Read Many times) or ERASABLE memory cell which makes it possible to write, erase and repeat the process. Variants of the

cell in fig. 9c include cells with only a single material, which simultaneously takes care of the memory and addressability (e.g. rectifying) functions.

In the prior art as illustrated in fig. 9c, the cells are formed by sandwiching the material in the cells (i.e. the memory and addressability layers) between a set of bottom electrodes that are typically pre-formed on a planar substrate, and a set of top electrodes, which are typically deposited onto the material in the cell and patterned by additive or subtractive processes. The simplest and most compact solutions are obtained when the materials in the cells are part of a layer that is applied globally, without patterning. This, however, implies certain drawbacks relating to restrictions on materials that can be used, as well as the ultimate cell density achievable (dependent on lateral leak currents in the cell materials).

In fig. 9d shows how a memory matrix with architecture equivalent to the one shown in fig. 9c can be made with crossing wires that are woven such that a memory cell is formed spontaneously at each point where wires in the weave cross. In the example shown, one set of wires extend in the x direction, the other set in the y direction. Each x wire consists of a monofilament metal, cladded by a polymer which forms a rectifying junction at the metal/polymer interface. Analogously, each y wire consists of a monofilament metal cladded by a substance which exhibits memory properties. An intimate electrical connection is formed between the cladding materials at the crossing point by mechanical force on the wires (pressure or stretching) during or after the weaving operation, assisted by thermal or chemical means. The basic structure in fig. 9c can be refined in different ways, e.g. by inserting electrically insulating separation filaments between the x and y wires in the matrix. Advantages of this woven approach are several as it provides a simple, virtually infinitely scalable means of creating passively addressed memory and switching matrices. Since the electrodes, memory and addressability materials are initially assembled as physically separated modules, one largely avoids chemical incompatibility problems which in alternative schemes severely restrict the freedom of choice in materials and architectures.

With present invention a reduction of electrical interference and related noise mechanisms shall be possible by using dual- or multiple-conductor structures as threads in the joining process.

In devices the size of present day chips and with the same wire density and operating frequencies, the fabric-like architecture shall generally be much more favourable with regards to electrical interference immunity since the wires will be separated by air which minimizes the problem (low dielectric constant). See B. Shieh & al. "Air gaps lower k of interconnect dielectrics", Solid State Technology, pp. 51-58 (February 1999). In other large devices such as displays which operate at relatively low frequencies, the woven architecture will also be favourable over existing technology.

However, devices that employ a very dense weave with mutually parallel or crossing filaments carrying signal currents at high frequencies and/or over large areas are also of particular interest in the present invention. Important examples are device architectures where memory cells, logic circuitry, amplifiers and interfacing electronics are integrated in self-contained configurations on a common substrate. Clearly, crosstalk shall be a major problem if the interconnects are laid out in close proximity to each other on the substrate without very careful attention to capacitive and inductive pickup elimination. Several of the most potent strategies in this regard are difficult or impossible to implement when traditional manufacturing technologies are used, e.g. a planar substrate with etched or deposited conducting stripes, typically in adjacent planar layers mutually separated by insulating layers.

Weaving, knitting, crocheting, knotting and/or stitching techniques provide a unique opportunity to create devices where one needs to suppress cross-talk involving conductors that carry currents within and to/from the apparatus, as well as achieving controlled signal transmission properties in those conductors. Key to this is to employ two- or multiple-conductor transmission lines with closely controlled geometries that provide balanced current paths and shielding of electromagnetic fields. Such ultra-thin transmission lines could be manufactured before being incorporated as filaments in the weave. Examples of such structures are twisted wire pairs, coaxial and certain types of stripline conductors as discussed in more detail in the following.

Using transmission lines with well-controlled electrical properties shall of course also present opportunities in addition to crosstalk suppression. An example is control of reflection properties at the terminations, of interest in

high-speed circuits. Specific examples of types of transmission lines that can be embodied in the apparatus according to the invention are given below.

Example 1: Twisted pair filament conductors

These are shown in fig. 10a. The properties are well-known and extensively described in the electronic literature. Good immunity against inductive pick-up from magnetic fields is obtained. In this connection reference can be made to P. Horowitz and W. Hill: "The art of electronics", pp. 456 & seq., Cambridge University Press, 2nd edition (1990). Each twisted pair of conductors could be used as one of the threads in the weaving process, for instance as a warp thread. This thread would then be a monolithic structure, with the conductor pair maintained in the desired positions relative to each other by a rigid dielectric matrix material.

Example 2: Coaxial line conductors

These are shown in fig. 10b. Each coax line, with inner and outer conductors as well as dielectric filling and coating materials, would constitute one of the threads in the weaving process. In general, for a lossless coaxial line having the radii r_a and r_b for the outside radius of the inner conductor and inside radius of the outer conductor, respectively, one has the following parameters.

Capacitance per unit length: (F/m) $$C = 2\pi\varepsilon / \ln(r_b / r_a) \quad (1)$$

Inductance per unit length: (H/m) $$L = (\mu/2\pi) \ln(r_b / r_a) \quad (2)$$

Characteristic impedance: (Ω) $$Zo = (\mu/\varepsilon)^{1/2} \ln(r_b / r_a) / 2\pi \quad (3)$$

Propagation constant: (m/s) $$U = (\mu\varepsilon)^{-1/2} \quad (4)$$

Here, μ and ε are the dielectric constant (electric permittivity) and magnetic permeability, respectively, of the fill material inside the coaxial line.

A major issue is that the transmission lines must retain the electrical properties of interest even as they are scaled down in size to ultra-thin outer diameters. In that connection, one may note from the expressions above that for lossless lines the characteristic impedances and propagation constants

remain unchanged under linear scaling of the physical dimensions. This naive approach is generally corroborated by more realistic and thorough studies, given the following certain assumptions:

Firstly, small cross-sections of the center and outer conductors shall imply that current paths must be short (typically a few centimeters), in order to keep resistive impedance low. This should present no problems in the present context.

Secondly, the thin outer conductor provides poor shielding of low frequency signals, highlighting the need for avoiding open loops by precisely controlled symmetric conductor geometries and uniform material properties in the line. The advantages in this connection of pre-forming the coax line before incorporating it into the substrate by weaving, instead of making such structures in situ are self-evident.

Thirdly, the current flows in the inner and outer conductors shall be balanced.

Fourthly, the lines shall operate at moderate to high frequencies (MHz to GHz).

Example 3: Flat conductor pairs

These are shown in figs. 10c-e, where 10c shows a planar line, 10d a strip line and 10e a symmetric strip line. Such transmission lines are high frequency signal compatible and well-known in the literature, cf., e.g.: P.Horowitz and W. Hill: "The Art of electronics", op. cit.

Example 4: Transmission lines in rolled-up devices

Novel devices of the generic type shown in fig. 11 shall now be discussed. Thin-film-based electronic and/or optoelectronic circuitry and components can as shown in fig. 11a be laid out on thin, flexible substrates which may in principle be of any shape or size. Thus, the size of the memory in data storage devices can be scaled by employing a substrate of appropriate size. Very large area substrates in the form of thin, flexible foils must be packaged into practical form factors. This can be achieved by stacking, folding or rolling together the thin device-bearing substrates as shown in fig. 11b, whereby also high volumetric densities ensue. A recurring problem with such schemes is how to provide electrical connections to all parts of the large areas involved. Thus, when thin sheets are stacked on top of each other,

connecting wiring to each sheet or between sheets in a stack may represent an unacceptable cost or reduce technical performance.

The rolled-up scheme in fig. 11b is attractive in that signal and power access can be established for a large-area, continuous structure, with only a few external connections entering the reel at the end of the rolled substrate. However, this solution implies that signal and power lines may become very long, extending along the full length of the rolled substrate. If traditional lithographic or printing technologies are employed to create these signal and power lines, signal attenuation along the length of the roll, reflections at signal branching and tapping points, and crosstalk between lines shall have a negative impact on technical performance, especially for high speed applications. Also, the creation of very long conducting lines by lithography or printing implies vulnerability to defects at points along the conductor. Instead, the present invention teaches the use of transmission lines in the form of multicomponent, balanced structures, i.e. micro-cables or -wires that can be manufactured to consistent high quality in a separate production step prior to being incorporated into the rolled sheet. The latter can be done in several ways, e.g. by stitching the transmission line into a ribbon that provides a uniform sheet-like substrate made from e.g. a polymer, or by the transmission line constituting one of the strands in a woven ribbon-like substrate which forms the rolled-up device, or by gluing or laminating a woven or braided length of multistranded material onto a ribbon of flexible sheet substrate.

*

Since the transmission lines have well-defined characteristics, precise impedance matching can be used to tap the lines at separate points along the length of the rolled-up sheet without corrupting the signals.

The power and signal lines may be optical as well as electrical. In the optical case, printing and lithography techniques are even less competitive as compared to the use of fibers or cables, even over short propagation distances: Although optical waveguides deposited or etched on planar substrates are well-known, e.g. as optical circuit elements, typical propagation distances are of the order of centimeters. Optical fibers, on the other hand, are widely used in signal transmission over thousands of kilometers.

The filament diameters of relevance in woven electronics applications shall typically be small, i.e. less than 100 microns. There exists a large body of knowledge within the general field of joining processes, etc, derived from the textile industry, and this encompasses technologies for handling ultra-thin filaments. In the present context, however, certain new elements are introduced, i.e. the requirement that at least some of the individual filaments shall possess explicit electrical and optical transmission properties. This shall not necessarily imply any major departure from traditional weaving technologies as long as monofilaments of metals or optical glasses or plastics are concerned. However, dual- or multiple-conductor filaments represent a novel aspect, both as regards the manufacture of the conductor structures themselves and their incorporation into woven devices.

Coaxial lines are of particular interest in the present context. Micro-coaxial cables are extensively used in low power level, high frequency applications, e.g. for radar signal conditioning. On the basis of information in avaiable literature the thinnest commercially available cables are approximately 0.5 mm in outer diameter, i.e. too coarse for fabric-like or woven electronics applications. On the other hand, there is no principal reason why much thinner coaxial cables could not be made. Indeed, there is presently being conducted research on nanoscaled electronic devices which also includes ultraminiature electrically conducting wires and sheathed cable, cf.: Y. Zhang et al.: "Coaxial nanocable: Silicon Carbide and Silicon Oxide Sheathed with Boron Nitride and Carbon", Science, Vol.281, pp. 973-975 (August 14, 1998).

Below the connection to specific conductors at selected locations inside the weave shall be considered in more detail.

In the fabric-like or woven electronics concept, there is a need to couple selected conductors in the weave electrically to components and other conductors, at well-defined points in the weave. This task is non-trivial in cases with a highly dense weave consisting of ultra-thin, possibly coated conductors running all the way from the edge of the weave. Some basic principles are the following. Firstly, a wire which is just stripped at the tip to make electrical contact while the rest of the wire is coated with an insulator can be locally inserted. The insertion of fibers or filaments locally is a common fabric technology. Secondly, an optical fiber or fiber bundle to send

signals to and from a photodetector/emitter can be inserted. Thirdly, post-insertion stripping or other treatment of localized areas on fibers, wires and filaments can be performed to gain access to the signal or power paths can be performed in a number of ways. For example, it will be possible using openings in a patterned mask lithographically defined directly on the weave or through a membrane in proximity thereof such that selected portions of the electrically insulating material surrounding conducting wires can be removed by etching or they can be modified by doping.

Alternatively, one may employ a beam which writes the positions where conductors are to be exposed, either by direct erosion (ion beam) or indirectly via a sensitizing beam.

In many cases, it is useful to separate conducting leads in the weave from each other by inserting intermediate insulating strands in the web. This simplifies the task of avoiding unintentional stripping of the coating layer on conductors close to the one to be connected. Another way of avoiding contact with near-lying strands is to employ coated conductors with different dissolution properties for the coatings, cf. the specific following examples.

<u>Example 5</u>

In a line of the "twisted pair" type consisting of two metal filaments with insulated coatings applied on each separately before being twisted together: There are two types of coating, one for the "hot", one for the "cold" filament, where the solubilities of the coatings in specific chemicals are different. The metal core in the "hot" filament would then be laid bare at a given location by selectively dissolving the coating on that filament using a chemical etchant which only attacks the "hot" filament coating.. The extent of the dissolution region could be controlled by exposure to the chemical etchant through a lithographically defined opening in a protective film.

<u>Example 6</u>

A variant of Example 1 is localized selective sensitization followed by chemical etching. The "hot" filament coating would be made soluble to a given reagent in desired locations, by exposure to the sensitizing agent (vapor, liquid, light, heat, particle beam....) through a lithographically defined opening in a protective film.

Example 7

The same basic principles as in Examples 5 and 6 can be employed with other types of selective stripping methods than chemical dissolution. Such methods include dry etching by photon (e.g. eximer laser) or particle irradiation, exploiting differences in etching rates of the coatings. The latter may be linked to, e.g. different hardness of the coating materials or to differences with respect to absorption of the irradiating photons or particles, or differences in etching rates

Example 8

Instead of using lithography to define the areas that shall be subjected to etching, one may use inkjet printing to either deposit the protective layer or the etching agent itself.

Example 9

Instead of using lithography to define the areas that shall be subjected to etching, one may use vector or raster scanning of a light or particle beam to achieve localized etching or sensitization. This way, several production steps can be avoided.

The advantages of the present invention are several. Electronic and optoelectronic functionality can be achieved on a wide scale of complexity and degree of integration in scalable two- or three-dimensional structures that are physically robust and flexible with respect to form factor. Integration of both optical and electronic circuits is simplified since material compatibility is not an important issue. Yet another advantage of the invention is the flexibility in the circuit design which can be continuously changed and adapted to meet specific needs. Wires can be looped and structured in such a way as create functional devices at any point or area in the woven matrices. The invention also provides a simple way to produce defect-tolerant architecture. In this connection reference can be made to the paper mentioned in the introduction by Heath & al., op. cit.

With the present invention a whole new class of electronics and/or optoelectronic apparatus will be possible. Particularly the invention offers the possibility of initially large-area flat devices which may be made as flexible fabric-like or woven structures and thus easily be form-adapted for specific purposes, in addition to being area-scalable. Such devices shall be well-suited for creating novel display devices and may as desired be made to

be integrated with active and/or passive known electronic, optoelectronic or optical devices.

PATENT CLAIMS

1. An apparatus comprising electronic and/or optoelectronic circuitry for implementing electronic and/or optical functions, wherein the circuitry is realized and/or integrated in two or more dimensions, wherein the circuitry comprises elements in the form of wires, fibres, ribbons, strips, or multicomponent filaments and/or combinations thereof, said elements interfacing in a predetermined pattern such that said circuitry are realized with intersections in physical or near physical contact between the elements thereof, wherein said predetermined pattern is generated by integrating physically two or more of said elements in a fabric-like structure by any of the following processes, viz. weaving, knitting, crocheting, knotting, stitching and/or combinations thereof, wherein said elements include transparent, non-transparent, conducting, semiconducting or insulating materials and/or combinations thereof, wherein at least some of said elements according to their material properties form electrical or optical transmission lines or isolators in said circuitry, said electrical or optical transmission lines conveying respectively electrical or optical energy between points and/or areas in said fabric-like structure, and or between the apparatus and its surroundings wherein at least some of said elements comprise spatially defined extended active regions, wherein at least some of said elements in portions of said fabric-like structure are adapted for emitting or absorbing electrical, chemical, mechanical or optical energy or for interacting with each other by an exchange of energy of the aforementioned kinds, wherein switching, coupling, emitting and absorbing mechanism in any case are realized by two or more active regions in respectively one or more elements and which are in mutual physical or near physical contact, whereby active areas in a contact of this kind realizes one or more specific functions or combinations thereof which implement, but are not limited to switching structures and/or diode structures with junctions specified by the materials in the contacting active regions, couplers for transmitting signals between the elements, memory structures for storing information and allowing addressing operations thereto to take place via further contacting, switching and/or coupling structures and wherein further emitting and absorbing as well as detecting mechanisms are realized by active areas exposed to the exterior, whereby active areas of this kind respectively form display structures for displaying visual information and images and/or sensor structures for sensing

and detecting specific physical or chemical influences which are conveyed by means of the elements of the apparatus or from sources exterior to the apparatus, said structures realizing all the above-mentioned mechanisms being integrated in the elements of the apparatus and forming a part thereof.

2. An apparatus according to claim 1, characterized in that the elements are provided in the predetermined pattern and form a substantially two-dimensional fabric-like structure.

3. An apparatus according to claim 1, characterized in that the elements are provided in the predetermined pattern and form a substantially three-dimensional fabric-like structure.

4. An apparatus according to claim 3, characterized in that the elements each has a length and is provided in a spatial distribution such that the positions of the end-points of the elements in the fabric-like structure define a spatial pattern or grid.

5. An apparatus according to claim 1, characterized in that some of the transmission lines are twisted pairs.

6. An apparatus according to claim 1, characterized in that some of the transmission lines are coaxial cables.

7. An apparatus according to claim 1, characterized in that some of the transmission lines are striplines.

8. An apparatus according to claim 1, characterized in that some of the transmission lines are optical fibres.

9. An apparatus according to claim 1, characterized in that the active regions of the elements are defined by exposing portions of the elements to the exterior surroundings thereof.

10. An apparatus according to claim 1, characterized in that active regions of an element are lengthwise extended therein.

11. An apparatus according to claim 1, characterized in that an active region of an element corresponds to an end-point thereof.

12. An apparatus according to claim 1, characterized in that some of the elements are provided with a protective shielding or cladding, the active

regions in these elements being provided by removing the shielding or cladding at selected portions thereof.

13. An apparatus according to claim 1, characterized in that the active regions of the elements are provided in selected portions of the elements exposed in the surface of the fabric-like structure or protruding therefrom at selected locations thereof.

14. An apparatus according to claim 1, characterized in that the active regions of the elements are defined by exposing portions thereof to spatially selective physical or chemical influences.

15. An apparatus according to claim 14, characterized in that some of the transmission lines are at least one conductor embedded in an exterior cladding comprising at least one organic semiconducting material, and that active regions are defined therein by contacting said transmission lines with other transmission lines of the same kind or with other transmission lines in intersections which comprise at least one non-isolated or unclad conductor only, whereby semiconducting junctions are formed at the contact points of said intersections.

16. An apparatus according to claim 15, characterized in that the semiconducting junctions are formed spontaneously upon contacting.

17. An apparatus according to claim 15, characterized in that at least one of the semiconducting junctions are a diode junction.

18. An apparatus according to claim 15, characterized in that the organic semiconducting material is a semiconducting conjugated or non-conjugated polymer.

19. An apparatus according to claim 1, characterized in that at least some of the elements over some of their length are shielded against any interactions in form of an exchange of energy between each other or the exterior surroundings, whereas one or more unshielded portions thereof are adapted for interactions of this kind by being in physical or near-physical contact with corresponding portions in other elements.

20. An apparatus according to claim 19, characterized in that the unshielded portions of the elements are located at the intersections thereof.

21. An apparatus according to claim 1, characterized in that an apparatus is a two- or three-dimensional optoelectronic display.

22. An apparatus according to claim 21, characterized in that the elements are signal transmission lines.

23. An apparatus according to claim 21, wherein the display is a two-dimensional display, characterized in that the elements are provided in a two-dimensional array.

24. An apparatus according to claim 23, characterized in that the elements intersect in a substantially regular pattern or grid, said elements at the intersections thereof being adapted for absorbing or emitting electrical or optical energy.

25. An apparatus according to claim 24, characterized in that a portion of at least one element in an intersection is a pixel of the display.

26. An apparatus according to claim 21, wherein the display is a three-dimensional display, characterized in that the elements are provided in a three-dimensional array.

27. An apparatus according to claim 26, characterized in that the elements intersect in a spatial regular pattern or grid, said elements in intersections thereof being adapted for emitting or absorbing electrical or optical energy.

28. An apparatus according to claim 26, characterized in that a portion of at least one element in an intersection is a pixel of the display.

29. An apparatus according to claim 26, wherein active regions of the elements are provided in selected portions of the element exposed in the surface of the fabric-like structure or protruding therefrom at selected locations thereof, characterized in that active regions of this kind are pixels in the display, said active regions being either a loop-like portion of an element or an end-point thereof.

30. An apparatus according to claim 1, characterized in that an apparatus comprises respectively one or more discrete electronic, optoelectronic or optical devices or combinations thereof.

31. An apparatus according to claim 30, characterized in that one or more of the discrete devices are physical or chemical sensors connected to at least one of the elements.

32. An apparatus according to claim 1, characterized in that one or more of the elements are a physical or chemical sensor.

33. A method for realizing and/or integrating circuitry in two- or more dimensions, wherein the circuitry comprises elements in the form of wires, fibres, ribbons, strips or multicomponent filaments and/or combinations thereof, wherein said circuitry is electronic and/or optoelectronic circuitry for implementing electronic and/or optical functions in an apparatus comprising circuitry of this kind, characterized by joining two or more elements into a fabric-like structure by any of the following processes viz. weaving, knitting, crocheting, knotting, stitching and/or combinations thereof, such that the elements interface in a predetermined pattern, realizing the circuitry with the elements intersecting in physical or near-physical contact in the fabric-like structure, and by providing spatially defined extended active regions in the elements at the intersections thereof, such that two or more active regions thus contacting each other in each case are realized with switching, coupling, emitting or absorbing mechanisms dependent on the specific physical or material properties of the active regions in question, said elements being made of transparent, non-transparent conducting, semiconducting or insulating materials and/or combinations thereof.

34. A method according to claim 33, characterized by providing the surface of the elements with a shielding or cladding material before joining into the fabric-like structure, and by removing said shielding or cladding material from some elements or from selected portions thereof at selected locations in the fabric-like structure, such that at least some of the selected portions form active regions with specific physical properties or material properties.

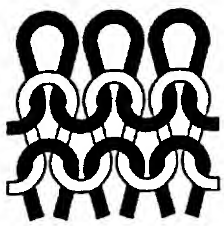

Fig.2a

Fig.2b

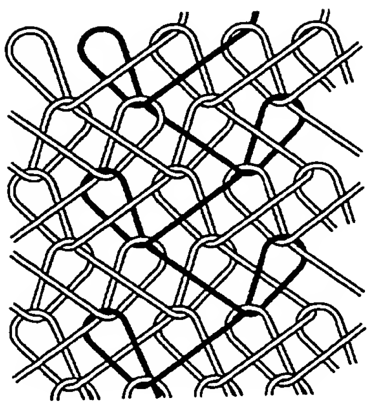

Fig.2c

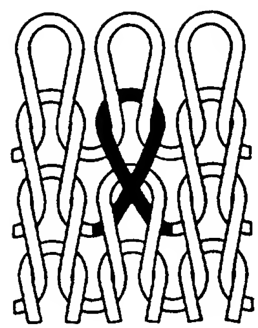

Fig.$2d_1$

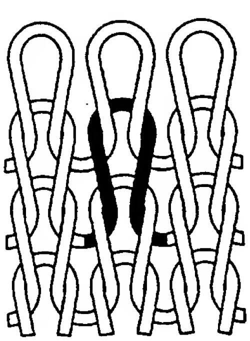

Fig.$2d_2$

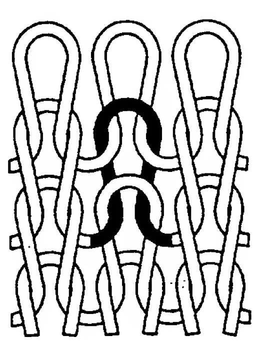

Fig.$2d_3$

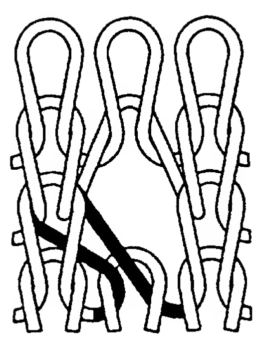

Fig.$2d_4$

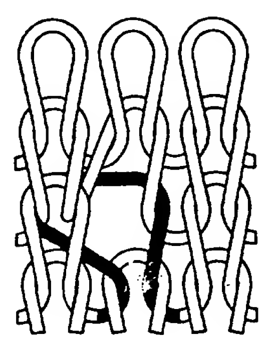

Fig.$2d_5$

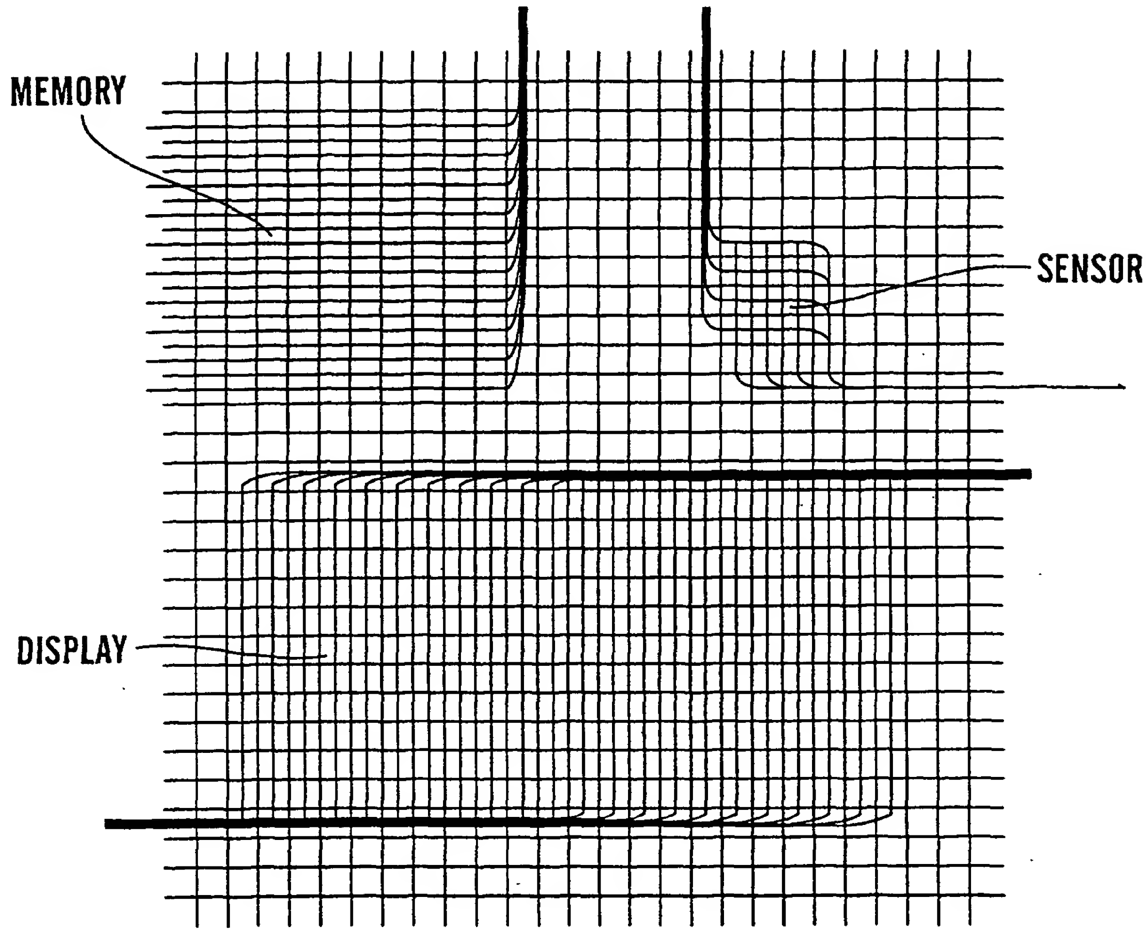

Fig.7